ATOMICS

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A bi-monthly journal devoted to the needs and interests of everybody concerned with the application of nuclear energy in all its various phases, in industry, in the medical and biological sciences and in the development of electrical power and heat.

ATOMICS

ANDREW W. KRAMER, *Editor*

Peaceful Uses of Atomic Explosives . . . Ever since the news of an atomic explosion in Russia was announced last year, the Russians have claimed that they were using atomic explosives in large-scale engineering enterprises. The implication is that in their far reaching construction program involving hydroelectric plants, canals, mines, roads, etc., large scale explosive operations are necessary and, *naturally,* the USSR would employ only the most up-to-date methods, namely, atomic explosions.

Knowning the Russian's disposition to disregard facts and truth these claims may well be taken with the proverbial grain of salt, or uranium, perhaps. There is another reason, aside from our distrust of Russian claims, that should make us doubt the Soviet assertions . . . the technical and economic feasibility of using atomic explosives for peaceful uses. These aspects of the case are discussed at length by Frederick Reins in the current Bulletin of the Atomic Scientists. Dr. Reins is a staff member of Los Alamos scientific Laboratory. Because of the high concentration of energy and the radioactivity hazard associated with atomic explosions Dr. Reins feels that their engineering applications are extremely limited in scope.

Except for the enormous quantities of radio activity that accompany an atomic explosion, it may be reasonably compared with an explosion from a large amount of ordinary high explosive. The comparison is not precise, however, because of the much higher concentration of energy and, hence, the higher temperatures in the atomic case. However, when the explosion proceeds sufficiently far and engulfs a mass of material equal to the mass of TNT . . . about 20,000 tons for a Nagasaki bomb . . . the temperatures become comparable to those found in the TNT blast, and the two kinds of explosions become roughly similar in the hydro-dynamic sense.

The large quantities of radiation from an atomic explosion, however, would definitely limit their possible use for blasting purposes. As Dr. Reines points out, the fission fragments from an atomic bomb are intensely radioactive, the total gamma-ray activity varying slightly faster than inversely with the time after the explosion. After one hour the activity is approximately 10^{10} curies; after one week it has decayed to 10^7 curies; and even after one year

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the level is 10^5 curies. This refers to gamma ray activity alone. The beta activity in curies is about equal to that of the gammas, although it is much less peretrating. A megacurie (10^6 curies) deposited uniformly over one square mile is sufficient to give an unshielded human being in the contaminated area a radiation dose of about 150 roentgens in one day. A lethal dose is in the neighborhood of 500 roentgens.

This means that any use in which the fission products are retained in a small region will result in a high and perhaps lethal level of activity for at least a period of months.

Even in the absence of radioactivity the use of such large scale explosions makes planned mining operations difficult. The unwieldy amount of pulverized material, the mixing of the limited amount of ore with a great quantity of debris, and the danger of a too great dispersal of exploded materials would limit the usefulness of atomic explosions. As to razing mountains (as the Russian's have implied) Dr. Rienes says, though the mass of earth which the atomic bomb is capable of moving is large in terms of freight car loads, it is small compared to a mountain. A hill about one quarter of a mile high and a quarter mile across could probably be blown apart, but one significantly larger could not be destroyed. It would take hundreds, perhaps even thousands of bombs to move any appreciable fraction of a mountain. The high cost of atomic explosives would almost certainly prevent their use for such purposes.

If it is desired to divert a river by blasting a large volume of rock, this might be acomplished by detonating an atomic bomb deep in the rock, In this case the radioactivity would soon be diluted by the moving water. However, it would certainly be necessary to chose a site many miles from a populated region and to have excellent meterological information as to potential rainfall. Even then, radioactivity would limit subsequent work in the vicinity.

Thus, it seems quite unlikely that the Rusians claims concerning the use of atomic explosives for peaceful purposes are true. Of course, if radioactivity is overlooked, more things become possible, but it is obvious that the Russians have chosen to ignore facts and to take all possible propaganda advantage of their newly acquired weapon.

Atomic Energy as a Human Asset

This article is based on an address given by Dr. Winne at the Atomic Institute of Connecticut State Educational Organizations at Hartford on April 26. Since much of the address was devoted to details which have received previous discussion in these pages, most of this has been greatly condensed or eliminated. His views on the probable use of atomic energy to the human race are presented as fully as possible

By HARRY A. WINNE

Vice President, General Electric Co., Schenectady, N. Y.

NO TERM EVER jumped from obscurity to front-page prominence so quickly as *atomic energy*. Prior to August 1945, when the first atomic bombs were dropped on Japan, it is reasonable to assume that over 99 per cent of our population had never heard the term and would not have known what it meant if they had heard it. After that fateful August probably 99 per cent had heard the term but probably 99 per cent felt, and still feel, that they do not know what it means. That is unfortunate, and unnecessary.

If for no other reason than that the atomic energy industry in this country is largely controlled and directed by our National Government and, therefore, supported by taxes which we all have to pay, we should know something about atomic energy. Despite the necessity for secrecy regarding technical know-how, a tremendous amount of information on atomic energy has been put forth in newspapers, magazines, books, and speeches. Much of this has been fanciful. Some writers and speakers have implied that atomic energy will provide free electric power, release us from toil and cure all our ills. Others see it only as a force of evil, released to a human race too immature to know how to handle it. Neither of these extremes is realistic.

There is a bewildering confusion in the minds of too many people—people who at first were anxious to learn and understand, but who now seem to have decided that they cannot hope to comprehend the mysteries of this spectacular form of energy. Of course, the scientific theories involved in the release of nuclear energy are difficult for the layman to grasp, but so are those concerning the chemical reactions in the burning of coal or wood, yet most every one feels that they understand the process of combustion. We do not have to be scientists to understand how to use, control, and protect ourselves against, fire. Neither do we need to delve into abstruse nuclear physics to grasp the significant facts about atomic energy.

The simple facts concerning the fission of uranium are no more difficult to understand than the process of combining oxygen with carbon in the com-

bustion of coal. Both involve the conversion of mass into energy. In the case of combustion we convert an infinitesimal part of the mass of the coal and air into heat energy. Only about one ten-billionth of the total mass of carbon and oxygen is transformed into energy.

In the fission of uranium-235, on the other hand we have been able, during the last ten years, to convert as much as one one-thousandth of the mass of the uranium into energy. This marks a ten million fold increase over what we get in combustion, therefore it constitutes a really long step ahead.

Of course, the process in the conversion of mass into energy in nuclear fission involves new things such as atomic reactors (piles) shielding, methods of control, an entire host of new gadgets which seem complicated, yet, if explained properly, none of these things are too difficult for the layman to understand. The whole process sounds complex but just suppose that we knew nothing about fire and someone tried to describe a coal-burning furnace. He would explain that only certain materials such as carbon would burn, and that even these would not burn unless they were arranged in certain ways so as to provide for a continuous supply of oxygen, and heated to requisite temperatures. He would tell us that the fire would give off heat radiation, which would be dangerous and therefore had to be surrounded by a shield of brick or iron. The material of the furnace must be such as to have ample strength when exposed to the heat radiation. We would learn that the fire can be controlled by adjusting the dampers to let in more or less oxygen.

If the wonders and dangers of fire had burst on upon our adult consciousness as suddenly, we would have been just as startled and confused as we were by the advent of atomic energy.

As has been explained many times in these pages, a rare type of uranium, U-235, is the only material found in nature which will support a nuclear chain reaction. As also explained, under suitable conditions, the more abundant type of uranium, U-238, can be converted to the element plutonium, a nuclear fuel which is now being produced in the piles at Hanford. It is also believed that the still more abundant element thorium can be converted to an artificial element thorium-233 which is fissionable.

WONDERS OF COMMONPLACE PHENOMENA

The conversion of unradioactive material into nuclear fuel is really an amazing accomplishment. Still, we must remember that much ordinary gas used for fuel and illumination has been made by feeding steam through a bed of white hot coke. True, this gas-making process is not conversion of atoms, but rather of molecules, but it is possible that if this process were as recent a development as the conversion of U-238 into plutonium, we would consider it equally noteworthy.

Again, we have learned that when certain elements are exposed to the radiations in an atomic pile they will become radioactive and in this way we have been able to transmute one element into another. Even gold can be produced, but the raw material is platinum, so we have not quite achieved the goal of the alchemists.

This achievement is remarkable but are not the results of the molecular changes we affect through the use of ordinary heat equally so? Think of our metallic alloys, our plastics, even the cakes which mother used to bake!

One more illustration. Those of us who have been in steel mills have seen the towering steel stacks rising a hundred feet or more above the ground, adorned with peculiar bulges and appurtenances. Into the top of these stacks are fed quantities of what looks like red dirt, white stones and black stones. Tons of air are forced into the bottom. And what comes out? Molten iron: slag, useful in making cement; and a gas which can be burned usefully. This, of course, is the common blast furnace. The red dirt is iron ore, the white stones, limestone and the black stones are coke. The blast furnace has been in use for many years, and we accept it as a matter of course, but are not the chemical changes it causes just about as amazing as anything we expect from atomic energy?

These few examples should make clear that many things which we daily accept as a matter of course, and use unhesitatingly, are really as amazing, and as difficult to understand technically, as is atomic energy. How many of us really know what happens—that is, from the standpoint physics and chemistry—when we light a fire, or turn on an electric lamp? Yet we know what fire and electricity can do, we know their possibilities and limitations, we know how to control them. We realize their possibilities for harm, their dangers, but we know how to protect against them, and we do not have unreasoning wild fear of them.

Too many people today are frightened by the mere thought of atomic energy. Under extreme pressure of war, the development of the atomic bomb brought to fruition one application much sooner than it otherwise would have come. This fact has unfortunately emphasized the destructive aspects of atomic energy. In the normal course of development military application would probably have been incidental.

ATOMIC ENERGY AS A HUMAN ASSET

Now some of the non-military uses of atomic energy will be considered—those applications which make it a "human asset".

It is a fair assumption that most people, when they think of peacetime uses of atomic energy, visualize it as a potential source of vast amounts of industrial power, and such it ultimately may prove to be, so suppose we pursue this possibility.

First, it must be realized that this energy will appear in the pile or nuclear reactor as heat. *We see no way of converting directly to electricity any significant amount of the energy released from the splitting atom.* So to use this energy we must get the heat out of the pile. One way of doing this would be to pump a liquid or gas through the pile to absorb the heat and then to pump the hot liquid or gas through a kind of steam boiler, which would generate steam to be used to drive a steam turbine-generator to produce electricity. In other words, in an atomic power plant, the atomic pile and some auxiliary equipment will merely replace the fuel-fired steam boiler, and from that point on the atomic plant will be the same as one using coal or oil as a fuel.

Consequently, it is likely that the first cost of an atomic power plant will be somewhat higher than that of a coal or oil-fired plant. As to operating cost, it is entirely possible, but far from certain, that in the decades to come the cost of nuclear fuel will be competitive with that of coal or oil. Today no reliable estimate of its cost can be made for there are too

many factors which we do not have the knowledge and experience to evaluate.

But in areas where electric power is today available readily and at reasonable cost, we must not look for any revolutionary reduction in power cost due to the advent of atomic energy. On the average, the cost of fuel represents only 20 or 25 per cent of the total price paid by the consumer for fuel-generated power, so if we got nuclear fuel free we could expect only 20 or 25 per cent reduction in power costs. Of course, this would be tremendously significant, but not in keeping with some of the more fanciful prophecies. Furthermore, the fuel will not be free, and the fixed charges will be higher.

On the other hand, because nuclear fuel is such an extremely concentrated source of energy, there is the very definite possibility that atomic energy may bring economical electric power to areas where the transportation costs on ordinary fuel are extremely high.

It is unlikely that small atomic power plants will spring up in every isolated area. To be efficient and economical an atomic power plant will necessarily be of large capacity, perhaps at least a hundred thousand kilowatts, and it may require a supporting chemical plant to reclaim partly used fuel.

The picture as to where atomic central power stations may first prove economical is not at all clear, but it appears reasonably sure that it will evolve favorably as our scientists and engineers carry along their developments. We are not yet ready technically to build a one hundred thousand kilowatt atomic power plant, and will not be for quite a long time.

OTHER POWER APPLICATIONS

What about other power applications? Well, we must remember that an atomic pile requires a radiation shield which, at least in the light of present knowledge, will weigh many tons, more than our largest motor trucks could carry. So, atomic-powered automobiles or trucks seem beyond realization.

It may be possible, as we learn more about making effective shields, to build a reactor within the weight and space limitations of a locomotive. It seems rather probable that this will some day be done. Such a locomotive could run long distances without refueling, and this is attractive.

There seems little doubt that we shall build atomic power plants suitable for shipboard service. An atomic powered ship could conceivably run for months without refueling, that is, as far as the power plant is concerned. It might be necessary to "refuel" the food lockers and refrigerators more often. This possibility is especially intriguing to the Navy, and the thought of an atomic-powered submarine, a real underwater ship which could make transocean cruises without need to surface, really gets the Navy people excited. The first specific purpose atomic power plant will undoubtedly be for shipboard use, and in fact, as has been announced by the Atomic Energy Commission, the design of two such plants is now under way.

Our United States Air Force is working intensively on the problem of atomic power plants for military aircraft. Because of the shield weight, this is an extremely difficult project, but may be solved in the decades ahead.

In my opinion, it is absolutely impossible today to state with assurance

what the economic effects of the power applications of atomic energy may be. I am optimistic enough to believe that ultimately atomic energy will make electric power even more available than it is today, and in some areas at least, at lower cost. I think it will find applications, such as on ships, where the tremendous concentration of energy in nuclear fuel gives it special advantages. We cannot forsee all of those today. Forty years ago, could any of us have foretold today's uses of petroleum and it derivatives?

So there are possibilities in atomic power, but when? There are many technical and economic obstacles ahead. Developments such as this do not come to fruition overnight, but a lot of work is being carried on under the auspices of the Atomic Energy Commission. One such activity is being carried on by the company for which I work, General Electric, namely the operation of the Knolls Atomic Power Laboratory at Schenectady for the Commission. We are designing an atomic plant for ship propulsion. From the design, construction and operation of this plant we shall learn a great many things that we need to know in order to build central station atomic power plants to generate electrical power for industrial and domestic purposes. In any case it is probable that atomic energy will only *supplement*, not *supplant*, present sources of power.

BY-PRODUCTS OF ATOMIC ENERGY

There is another phase of atomic energy development which probably will have beneficial economic and social effects much sooner than will atomic power plants. This is the use of radioactive isotopes of many elements, whose production in large quantity has been made possible through the medium of the atomic pile.

Not so many years ago we thought that an element occurred in only one form; that, for example, all atoms of carbon were exactly alike. Now we know that most elements have two or more different forms of atoms, or isotopes. Some of these, particularly those produced in an atomic pile, are radioactive, that is, they give off radiations similar to X-rays or to those from radium.

The atomic pile is a powerful new tool for producing radioactive elements of all types. In almost 50 yr only a few pounds of radium have been made available. One pile can generate as much radiation as several hundred tons of radium.

By using radio-isotopes as tracers we are learning much about the functioning of the human body, and its use of materials. It has been shown that all components of the body, muscle, bones, teeth, blood, are constantly being renewed. The surprising rapidity with which life processes take place has been revealed.

Radio-isotopes are being used in studying the blood circulatory system. Studies of anemia have suggested a possible new treatment. They are useful in diagnosis particularly in circulatory diseases. Radio-phosphorous has been used to locate brain tumors for surgery.

Radio-isotopes may prove of value in treating certain disorders. It is hoped that they will prove useful in the study, and perhaps the treatment, of cancer.

In agriculture, radio-isotopes can be traced in their travels from the soil up through the plant structure. Thus information as to when plants make use of various types of fertilizer, and the optimum location for

application of fertilizer, has already been gleaned. Unquestionably these new tools will help us to learn a great deal about the life processes of plants, knowledge which will be very useful to the human race.

Radio-isotopes permit us to trace the migrations of various elements in chemical and metallurgical processes.

The extremely important part that radioactive isotopes are playing in our search for knowledge is evident. Unquestionably they are bringing about a tremendous acceleration in research in medicine, botany, chemistry, and other fields. Certainly the radioactive products of the nuclear reactor are having more immediate beneficial uses than is power produced from it, and their ultimate effect may well be more important to the human race than the power development.

Thus, it will be clear that atomic energy is a *human asset*. Incidentally, just out of curiosity I looked up the definition of the word "asset". The first dictionary to which I turned said that an asset is a part of one's assets, and then gave this definition of "assets":—"The entire property of all sorts, of an insolvent or bankrupt, or of a person, association, corporation or estate, applicable or subject to the payment of his or its debts; or the property of a deceased person subject by law to the payments of his debts or legacies".

This reminded me too much of those prophets of gloom who see in atomic energy only an agent for destruction of the human race. So I looked in another dictionary and found this definition:—"Asset—that which is a resource, as, character is an asset".

That definition, to my mind, well fits atomic energy. It is a resource, a very definite one, a resource for human benefit. It is very unfortunate that the memory of spectacular demonstrations of the destructive power of atomic energy seems to arise in everyone's mind at the mere mention of the words.

The situation seems akin to that which would exist if our only experience with fire had been the terrorizing one of being surrounded by a raging forest blaze. Or suppose our only experience with electricity had been that of a crashing lightning stroke killing someone dear to us. Under these hypothetical conditions, would we have considered either fire or electricity to be human assets?

Yet I am sure that in the light of the knowledge we have today of these great servants of mankind, fire and electricity, all of us think of both of them as important human assets.

Many of us had hoped that even the atomic bomb itself might prove a great human asset, by acting as the motivating force to bring about an agreement and understanding among nations which would help to prevent war in the future. That hope now seems rather unlikely of early realization, unfortunately.

But that it will prove an asset in the material sense I have no doubt. I think it will prove to be a welcome supplement to our fuel supply in general, and the outstanding fuel in certain unusual situations. I am not the least discouraged, for the long pull, by the high cost of presently proposed atomic reactors. We do not have enough engineering knowledge and experience in this field as yet to build low cost power plants. But that will come. We are in much the same position in this field today as we would

have been had we tried fifty years ago to build a gas turbine to run at today's gas turbine operating temperatures. We might well have thought we must build the combustion chambers and buckets of platinum! Wouldn't that have made a nice expensive piece of jewelry!

It may be that we are trying to force developments in atomic energy at too fast a pace. If that be true, it can prove very expensive, and can conceivably even delay attainment of the ultimate goal, through building up a false belief in its impossibility. Let me refer again to the gas turbine. Forty or fifty years ago we knew its fundamental principles of operation, just as we have similar knowledge today about atomic energy. But we did not have adequate materials and processes.

Well, one may ask, couldn't they have been developed very quickly, if large amounts of money had been available. I think not. We did not have the metallurgical knowledge fundamental to such development. More than that, we did not have the tools with which to obtain that knowledge. We did not have adequate microscopes, X-ray equipment, spectroscopes. We did not have electric furnaces for heat treatment, nor electric welding for fabrication. As a matter of fact some of the essential elements in today's high temperature materials had not been discovered.

So let us not be discouraged if it takes 20, 30, or 40 years before atomic energy has a significant effect on our power supply.

Atomic energy is already proving an asset through making radioactive isotopes available to our doctors, our botanists, our chemists, our scientists of all types, who are putting them to good use. I am sure we do not begin to conceive all the benefits which these new tools will bring to the human race as we gain more knowledge about them.

Status of Accelerator Program

Particle accelerators or atom smashers are among the most important tools in nuclear research. The 184-in. cyclotron at the AEC's Radiation Laboratory, Berkeley, is at present the greatest of these machines. However, two AEC financed machines now being designed and under construction will dwarf this huge machine.

At Brookhaven National Laboratory scientists are building a proton synchrotron (the Cosmotron) which will impart energies of from 2 to 3 billion electron volts to sub-atomic particles. Scientists are running model tests of the huge magnets for this machine. The building excavations are complete and the foundations have been poured for more than a year to permit adequate settling before the huge superstructure is added. Equipment has been on order for many months and is now being received.

A still greater machine—the Bevatron—is being built at the Berkeley Radiation Laboratory. A quarter-scale model of this enormous machine was built in record time to test the feasibility of the full-scale machine. Tests of the model have proved that the great machine will operate as planned and construction is being rapidly pushed. Steel for the 10,000-ton ring-shaped magnet is being shipped and the machine is expected to be ready for preliminary testing by mid-1950.

Nuclear Power Engineering

Part XI. Neutron physics and nuclear power engineering . . . Factors involved in the design of reactors . . . Nuclear reactions in atomic piles . . . The Bohr theory of nuclear reactions . . . The Gamow liquid drop theory . . . Calculation of surface forces and density of atomic nuclei . . . Relation of surface forces and electric forces in liquid drop theory . . . Equilibrium of nuclear forces

By ANDREW W. KRAMER

IT WILL BE EVIDENT, from the last two chapters, in which certain neutron characteristics and reactions have been described, that the subject of *neutron physics* is not a simple branch of study. Indeed, it is very complex, and, this series of articles, can provide no more than an introduction to the subject. A more detailed study would involve considerably more mathematics than could be justified in this general consideration of nuclear power engineering.

Enough has been given in the last two chapters to indicate the kind of elements the nuclear physicist has to deal with. Atomic energy phenomena may be divided broadly into two parts, one involving the interaction between atomic nuclei and high speed neutrons (as in the atomic bomb) and the other, involving slow speed neutrons, as in the nuclear reactor.

In the atomic reactor, which is of primary concern in the production of power from atomic energy, high speed neutrons produced by fission of uranium or other fissionable material, have to be slowed-up so as to increase the *cross section*. The cross section, we have seen, is a function of the speed; the slower the speed, the greater the cross section or the probability of capture by a fissionable nucleus.

Thus, the nuclear physicist or the engineer designing a reactor must have at his disposal, all possible data concerning nuclear structure, cross section, collision and scattering processes, neutron diffusion, as well as many other factors that are inherent in the problem. In the nuclear reactor,

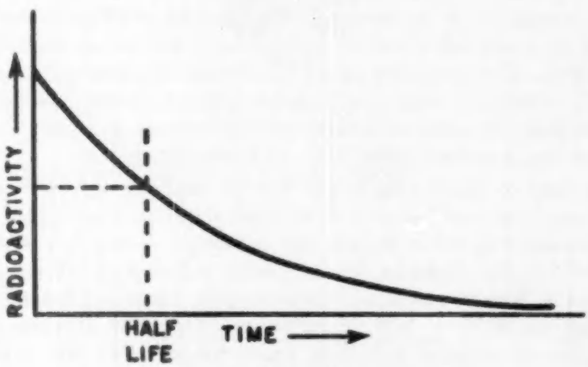


Fig. 1 The radioactive decay curve

some of the neutrons, after being slowed down by a moderator of some sort, are captured by other fissionable nuclei, produce more neutrons and thus perpetuate a chain reaction. Such a chain reaction is possible, however, only in the case where not too many of the neutrons produced leak out of the pile or are unproductively absorbed by non-fissionable nuclei before they can produce fission. This introduces the factor of critical size. The surface area of a small reactor is so large compared to its volume that more neutrons leak out than are produced to supply this loss and at the same time sustain a chain reaction. In a successful pile (another name for a reactor) a delicate balance must be attained in the neutron economy so that the rate of production is equal to the number needed to sustain the chain reaction plus those which inevitably escape from the surface.

A large volume has a smaller surface in proportion to the volume than a small volume. In the case of a sphere, for example, the surface area varies as the square of the radius whereas the volume varies as the cube of the radius. Since the number of neutrons produced (assuming homogeniety) in a pile is dependent upon the volume, it is obvious that a critical point will be reached where the number of neutrons produced will more than compensate for those that leak from the surface; this is the critical size of the pile.

These facts are fairly well known to most everybody who has given this subject any attention at all but they are reviewed here for sake of clarity.

NUCLEAR REACTIONS IN ATOMIC PILES

In the design of atomic reactors it is necessary to know what happens to fast neutrons produced by fission, how they move about in space and how they are slowed down by matter. In passing through a moderator material such as carbon or heavy water, the fast neutrons collide with the nuclei of the moderator atoms, and in such successive collisions lose most of their energy. Their path will consist of many short zigzags of various lengths. After they have lost most of their energy in this way they may be captured either by fissionable or non-fissionable nuclei, thus forming a *compound* nucleus.

The second step in the reaction, provided the neutron has been captured by a fissionable nucleus, is the breaking up of the compound nucleus into the reaction products. Once the incident neutron has entered the nucleus, the kinetic energy of the incident particle and the additional binding energy contributed by it are rapidly distributed among all the neutrons and protons of the nucleus. The breaking up of the compound nucleus can take place only after a relatively long time because a large number of collisions (inside the nucleus) is required before enough energy is likely to be concentrated on one or a group of nucleons to cause disruption.

The lifetimes of compound nuclei are of the order of 10^{-12} to 10^{-14} sec which is very long compared to the time required for a fast neutron to traverse a distance equal to the nuclear diameter. A neutron with an energy of only 0.5 Mev, for example, would have a velocity of 10^{9} cm per sec, and at this speed it would traverse a medium size nucleus (having a diameter of 10^{-12} cm) in $10^{-12} \div 10^{9} = 10^{-21}$ sec. Thus the lifetime of the compound nucleus is roughly a billion times longer than the time necessary for a neutron to travel the diameter of a nucleus.

According to the Bohr theory of nuclear reactions—and this theory has been very successful in explaining many features of reactions induced by particles—the disintegration stage of a nuclear reaction can be treated independently of the formation of a compound nucleus. The basis of this assumption is the classical picture of a nucleus as a system of particles with very strong interaction and short range forces. If the incident particle comes within the range of the forces, its energy is quickly shared among all the constituents well before any re-emission can occur. The state of the compound nucleus is now no longer dependent on the way in which it was formed. A given compound nucleus may be formed in different ways and it may also be able to disintegrate in different ways. Thus a compound nucleus may emit a proton, a neutron, or an alpha particle. According to the Bohr theory, each mode of disintegration has a certain probability which is independent of the mode of formation of the compound nucleus. The process of disintegration is essentially of a statistical nature. Different nuclei eject particles at different moments over a certain period of

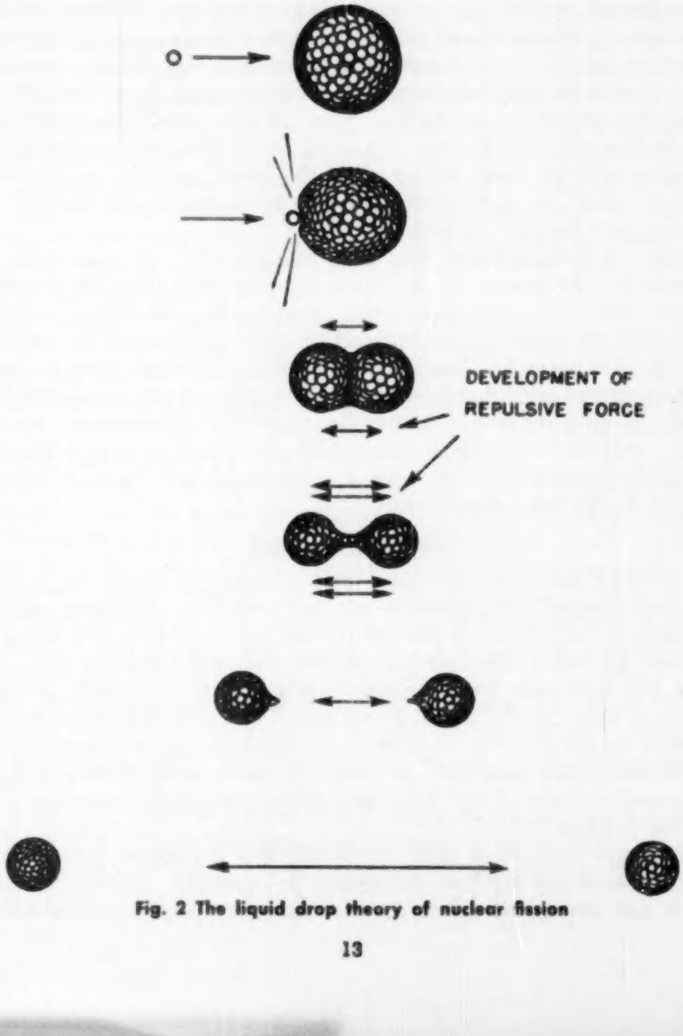


Fig. 2 The liquid drop theory of nuclear fission

time, the intensity of emission gradually decreasing as indicated in Fig. 1. This curve is the exponential decay curve referred to in an earlier chapter concerning radioactivity.

The nucleus of the atom can be considered as a ***condensed phase*** of the neutron-proton system in the thermodynamic sense. The neutrons and protons form a state in which they are densely packed so that the nuclear matter has definite boundaries. The volume is proportional to the number of constituents. By assuming a spherical form, it becomes possible to introduce a nuclear radius $R = r_0 A^{1/3}$ where A is the number of constituents and $r_0 = 1.45 \times 10^{-13}$ cm. The results from this formula are in fair agreement with values from experiments in which the size of the nucleus is involved. Furthermore, the characteristic properties of nuclear matter, especially the close proximity of all constituents, are maintained even if the nucleus is excited to energies high enough so that it might emit one or more constituents. This is valid because the probability of emission of the constituents is very small, so that the nucleus is in a well defined state before having emitted the particle. It is in a state which has essentially the same properties as the lower excited states which do not emit particles.

This is very different from the situation with excited *atoms*. An electron escapes very rapidly if excited above ionization energy and no states of the atoms in which the electron is still close to the atom could possibly be defined in this region of excitation. The nuclear conditions however, are similar to that of a liquid drop or a solid body. The heat energy of such a system may well be much higher than the work necessary to evaporate a single molecule. The state, before emission of this molecule, has a life time long enough to be well defined.

Emission of a constituent (an electron, a proton or a neutron, or an alpha particle) by means of nuclear excitation may then be divided into two steps: first, the excitation to the excited state, and then the emission of the particle from the excited state. The analogous process in atoms, however, must be described in one single step, since the time interval until the electron leaves the atom is not long enough to define a regular quantum state in which the electron is still within the atom. This assumption is not fulfilled for very high excitation energies of the nucleus. Where the energy of the incident particle is very high, the resulting emission is no longer independent of the way of excitation.

LIQUID DROP THEORY

The nucleus has been compared with a drop of liquid. In a drop of water, for example, the molecules are kept together by forces of mutual attraction. The molecules in the interior of the drop feel no average force because on all sides they are surrounded by neighbors. At the surface, however, the molecules have neighbors only on one side, hence are pulled towards the body of the drop. From this viewpoint the forces exert the same effect on the drop as if it were wrapped in an elastic envelope, an effect mathematically described as surface tension. This tension determines the most stable shape of the drop as a sphere, the body with the smallest surface for a given volume.

The analogy between a drop of liquid and a nucleus serves to some extent in visualizing nuclear reactions. In ordinary liquids the surface tension is not strong enough to prevent completely any part of the drop

from flying off. Parts may be lost in two ways. Molecules which acquire sufficient energy by thermal agitation, may overcome the surface tension and leave the drop. This is called evaporation. The drop as a whole may vibrate about its stable, spherical configuration and occasionally split into two parts of more or less equal size. This is particularly true of large drops and this is why rain drops never exceed a certain size. Of course, the forces acting in a drop of liquid and in nuclei are entirely different in nature but they exhibit a common property in that they both exert cohesion.

In the process of fission of a heavy nucleus such as uranium 235, when the U-235 nucleus captures a neutron, its energy of *condensation* becomes available and this produces a violent commotion inside the neucleus which may be described as heating. This hypothetical temperature of course bears no relation whatever to the temperature of the whole body as measured by a thermometer, but as far as the interior of the nucleus is concerned, the action is similar. This may cause the nucleus to elongate as shown in Fig. 2 and cause it to take the shape of a dumbbell. Since, the nucleus is filled with protons which tend to repel each other, there comes a time when the two spheres represented by the ends of the dumbbell develop an overall repulsive charge which becomes more intense as the elongation proceeds and this cumulative action finally results in the violent fission of the two halves.

SURFACE FORCES AND DENSITY OF NUCLEI

This droplet theory of the nucleus has been explained very clearly by Gamow.[1] Dr. Gamow analyzes the forces of surface tension in a drop of liquid according to classical theory and shows that a similar phenomenon may operate in the nucleus of the atom. The magnitude of the forces involved are infinitely greater in the case of the nucleus, however. According to Gamow, "different nuclei are considered as droplets of a universal *nuclear fluid.*"

If this theory is valid, one of the first important conclusions to be drawn is that the volumes of the different nuclei must be proportional to their weights since the density of the *nuclear fluid* must always remain the same, independent of the size of the drop which it forms. Direct measurements of nuclear radii completely confirms this conclusion. Throughout the entire range of the natural system of elements the radii of atomic nuclei vary as the cube roots of their weights. The radii of the nuclei of oxygen and lead for example, weighing 16 and 206 units respectively (with respect to hydrogen) have diameters of 3×10^{-13} and 7×10^{-13} cm, respectively. This is in complete agreement with the cube root proportion.

Now, the actual weight of the hydrogen atom is 1.66×10^{-24} gram. Thus the weight of the oxygen nucleus is $16 \times 1.66 \times 10^{-24}$ or 2.66×10^{-23} grams, and that of the lead nucleus. $206 \times 1.66 \times 10^{-24}$ or 3.42×10^{-22} grams.

Since the volumes corresponding to the two radii are 1.13×10^{-37} and 1.44×10^{-36} cubic centimeters the *density* of the nuclear fluid in both instances will be found to have a value of 2.4×10^{14} gram per cubic centimeter.

This, as Dr. Gamow points out is truly a density which challenges our imagination. If the nuclear fluid, instead of being dispersed through space in the form of minute droplets separated by vast distances in which

[1] Atomic Energy in Cosmic and Human Life. By George Gamow. The Macmillan Co.

only a few electrons are present, could be collected to form a continuous material, *one cubic centimeter* of it would weigh *two hundred and forty million tons!*

Quite understandably, a substance with such a high density could have a correspondingly high surface tension. In the measurement of surface tension of ordinary liquids, we usually use the force acting on a unit length of the free surface boundry. If, for example, a soap film is spread in an area formed by a U shaped wire as in Fig. 3 and another straight piece of wire is laid across it, the pull (to the left) on the movable cross bar will be a measure of the surface tension of that film. From actual measurement of this kind, the surface tension of water is known to be 75 dynes per square centimeter. In mercury the surface tension is 465 dynes per square centimeter. A dyne is approximately equal to the weight of 35 millionths of an ounce.

It is of course impossible to measure the surface tension of the nuclear fluid in any such manner but it is possible to measure it by the amount of electrical energy required to deform or break up a nuclear droplet. In this way, the surface tension of the nuclear fluid has been determined to be 93,000,000,000,000,000,000 dynes per square centimeter.

Knowing the value of the surface tension of the nuclear fluid it, at once, becomes possible to calculate the amount of energy involved with any change in the total free surface of the fluid. In the case of the soap film, any increase in the free surface requires that work be done against the surface tension—pulling the cross wire to the right. Similarly, a decrease in surface will liberate a certain amount of surface energy. Numerically, the amount of energy per unit surface as expressed in ergs, is given by the same number as the surface force, namely, 93×10^{18} ergs per square centimeter.

To calculate the total surface energy of the nucleus, therefore, it is merely necessary to multiply its surface by 93×10^{18}.

Since it is inconvenient to consider surface areas of a nucleus, the surface energy of one nuclear particle located on the surface has been found useful. The diameter of a neutron or proton is on the order of 3.2×10^{-13} cm, hence, each of them will occupy an area on the surface of a nucleus $3.1416 \times 3.2 \times 10^{-13}$ or 10×10^{-26} or simply 10^{-25} square centimeters. In other words, there will be 10^{25} particles per square centimeter. If, we now divide the total surface energy by the number of particles it is found that there are roughly 9.10^{-6} erg or about 5 Mev of energy per particle. This represents the energy necessary to remove

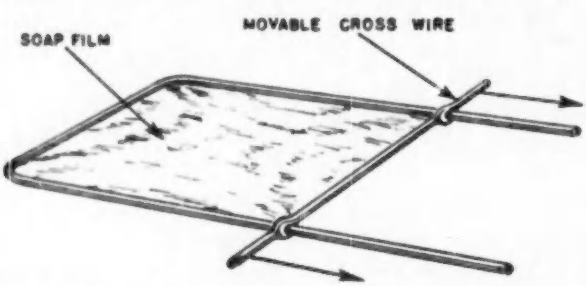


Fig. 3 Drawing showing the principle of measurement of surface tension of liquids

one proton or one neutron from the surface of the nucleus against the force of cohesion.

Knowing that the forces involved in the nucleus are somewhat similar to those concerned with a droplet of ordinary liquid, it is reasonable to suppose that the action of nuclei will be somewhat similar to the action of liquids. We know, for example, that when two drops of rain, rolling down the surface of a window happen to touch, they immediately coalese into a larger droplet. The fusion of two such drops is due to the surface tension forces which tend to reduce the total free surface of the liquid. The surface of one big droplet is smaller than the combined surface of two half-size droplets. As mentioned earlier in this article, the surface of a sphere varies as the square of the radius, whereas the volume varies as the cube of the radius.

The fusion of two droplets, therefore always results in the liberation of surface energy. Conversely, it is necessary to supply energy in order to break a droplet into two or more parts. Such a process would never happen without external influence. If there were no other forces at work than those of surface tension, all the nuclei in the universe would gradually condense into one mass of super-dense nuclear fluid.

It will be recalled, however, that forces of great repulsion are also inherent in the nucleus—the coulomb force between the protons. These electric repulsion forces between the protons act in opposition to the surface tension forces and this tends to prevent the fusion of any two nuclei except under unusual circumstances. As a matter of fact this coulomb force tends to disrupt every nucleus into still smaller ones.

FURTHER EXPLANATION OF DROPLET THEORY

Now, with this understanding of the forces at work, we can better understand the fission of the nuclear droplet depicted in Fig. 2. As long as a droplet retains its spherical shape, all forces are in balance. The instant, however, that the body deforms by the application of external force, a slight elongated shape is produced and a conflict of the two opposing forces begins at once. The surface tension tend to return the nucleus to it original spherical shape but the electrical forces between the positive charges at the ends of the droplet endeavor to increase the existing elongation and will try to break the nucleus into two halves.

The ultimate result, of course, depends upon the total amount of energy available in the system, that is, the combined energy of surface tension and the electric force. Since fission of a droplet leads to an increase of surface energy, the surface tension force alone would never cause the droplet to break up spontaneously.

With respect to the electrical forces, from elementary theory we know that the electrical energy of a charged sphere is given by the square of its charge divided by its radius. Thus, if we consider the two drops resulting from the fission of a larger drop into two equal halves, the radi of the small drops will be 1.26 times smaller than the radius of the original drop. This follows from the fact that since the total volume of the large drop is twice the volume of the small drop, the radius of the large drop is $\sqrt[3]{2}$ or 1.26 times larger. The electric energy of each droplet then will be $(\frac{1}{2})^2 \times 1.26 = 0.315$ times that of the original large

drop. Consequently, the combined electric energy of the two halves will be only 2 x 0.315 = 0.63 of the original amount.

It is evident, therefore, that although the surface energy is increased by the fission of a large nucleus into two halves, the total electrical energy is reduced.

EQUILIBRIUM OF NUCLEAR FORCES

This brings us to the last phase of this study of the equilibrium of nuclear forces, under what conditions will a nucleus break up? Whether or not a nucleus breaks up spontaneously depends upon the relative values of the surface tension energy and the electric energy. If the reduction of electric energy overbalances the increase of surface tension energy the nucleus will break up, the balance of the energy being transformed into the kinetic energy of the fragments. If it does not overbalance the surface energy, the nucleus, no matter how greatly deformed, will resume its original spherical shape.

Thus, if we compare the relative values of surface tension and the electric forces in the nuclei of the different elements of the periodic system, proceding from the light to the heavy end of the table it will be found that the surface energy, which is determined by the total surface of the nucleus, increases comparatively slowly since it is proportional to the $\frac{2}{3}$ power of the atomic weight. This is the square of the cube root, so if the atomic weight increased by a factor of, say, 27, the surface increases by a factor of only $(\sqrt[3]{27})^2 = (3)^2 = 9$.

The electric energy, on the other hand, increases as the 5/3 power of

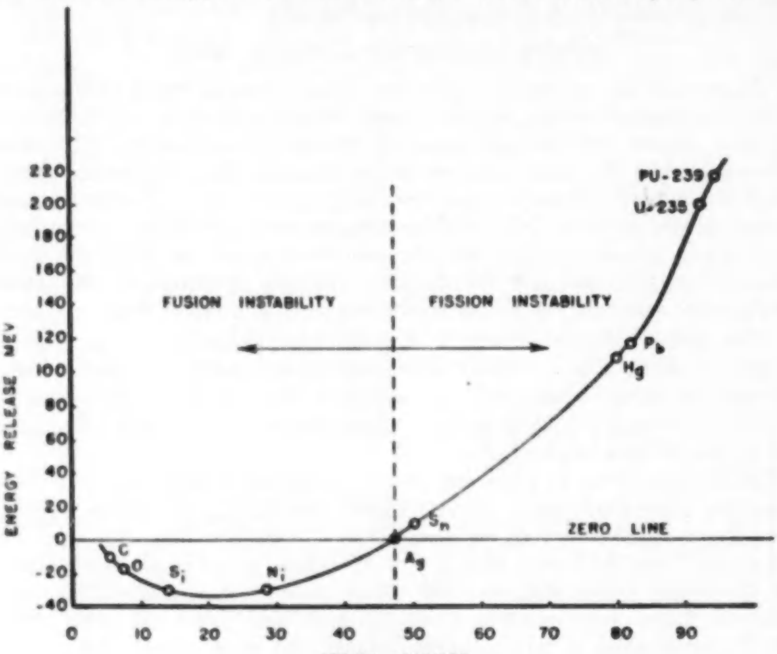


Fig. 4 Curve showing the energy liberation resulting from nuclear reactions in the various elements of the periodic table

the nuclear charge and this in turn is roughly proportional to the atomic weight. As a consequence the electric energy of the nucleus increases considerably faster than the surface energy and so while the surface forces may succeed in maintaining the stability of light nuclei, in the heavier elements they will be overcome by the electric forces whose tendency is to break up the nucleus into smaller parts.

In a detailed study of the balance of nuclear forces, Bohr and Wheeler, in 1939, were able to predict the exact limit beyond which disruption of fission of an atomic nucleus must be expected to take place. It was determined that the instability of atomic nuclei with respect to fission begins just about halfway up the periodic system of elements, approximately near the position of silver.

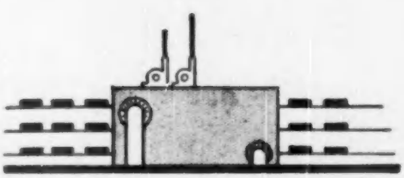
For this reason, the nuclei of all elements heavier than silver are potentially unstable and will break up under the action of sufficiently strong excitation, with the consequent liberation of considerable quantities of internal energy. This is what occurs in the fission of uranium.

In the case of the lighter elements, the surface forces of the nuclei easily overcome the electric repulsive forces so that we can expect spontaneous fusion whenever two light nuclei with a combined weight less than that of silver come together.

This situation gives rise to the curve shown in Fig. 4 which was calculated by Bohr and Wheeler, and which gives the energy balance associated with the breaking up of the atomic nuclei into two halves.

This curve indicates that for the elements of the upper half of the periodic table, the balance is positive, i.e., the process is associated with the liberation of energy. In the case of the lighter elements the curve goes below the zero line which means that energy would have to be put in to break up such nuclei. It follows also, that in this region, it is not fission but the fusion of two nuclei that will lead to the liberation of energy.

These facts have already been amply verified by experiment, the greatest of which, of course, was the explosion of the first atomic bomb at Alamagordo. The facts also make evident that from the viewpoint of alchemical transformation, all chemical elements with the exception of silver are in a metastable state, and can liberate vast amounts of hidden internal energy either by fusion in the case of the lighter elements or by the process of fission in the heavier elements.



Robot for Radioactive Areas

Ingenious one-armed robot developed by G-E engineers performs a variety of operations by remote control. Mounted on wheels running on rails the device can manipulate valves, handle a fire hose, deliver a 4-ton push and do other things besides

A ONE-ARMED ROBOT on wheels, which can close doors, turn valves, take apart and reassemble complex machinery, and perform virtually every task the human hand can perform, has been developed by General Electric engineers for work in radioactive areas.

The device, known as a "tool dolly," is rolled into radioactive areas where men cannot go, and is operated by remote control from a shielded adjacent room. It moves under it own power along narrow-gage railroad tracks. Power and control are supplied through six cables which lead to the power source and control devices.

The tool dolly was developed by engineers of the G-E General Engineering and Consulting Laboratory for use on projects which the company is conducting for the Atomic Energy Commission.

The dolly weighs approximately five tons, and resembles a railroad

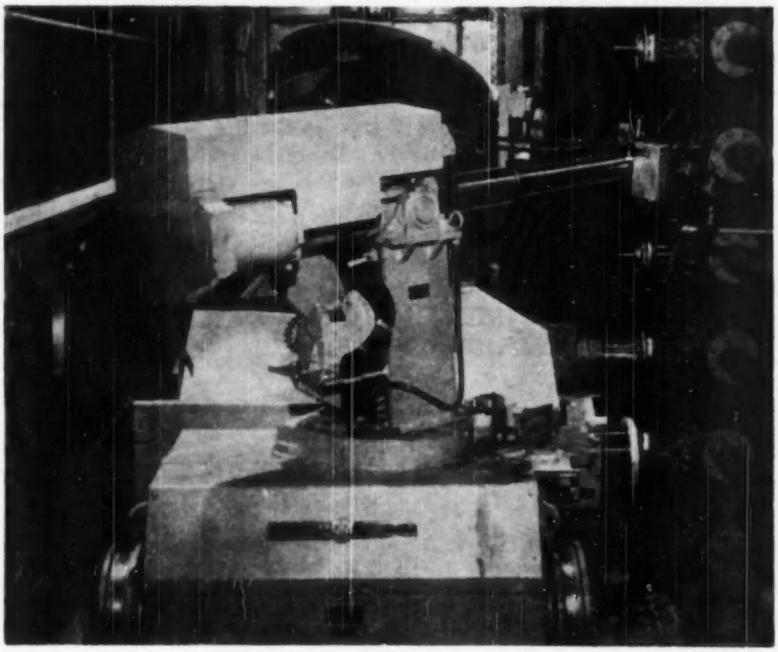


Fig. 1 One of the 5-ton tool dollies turning valves at Hanford, Equipped with electric feelers the valve turning arrangements indicate whether the valve is properly centered in the grasp of the turner

Fig. 2 Safe in a protected booth, an operator uses remote control to put the robot through its paces. Controls are mounted in two boxes about the size of small suitcases. Control panels are equipped with lights which indicate the position of the dolly's tools with respect to the apparatus being worked upon when it is impossible for the operator to watch the work

Fig. 3 For contact operation of the tool dolly, there is an instrument panel on top of the mechanical monster. The three-foot mirror can also be manipulated by remote control when an operator wants to see what the device is doing, and cannot see its work in direct line of sight. The mirror can be turned vertically or horizontally by remote control

handcar with a small caliber deck gun mounted on it. The gun-like part of the apparatus is a telescoping arm, on the end of which are double clamps, similar to artificial hands used by amputees. The arm can be extended or shortened, raised or lowered, by remote control. The "hand" itself is capable of a wrist-bending motion, rotation, and gripping. Persons

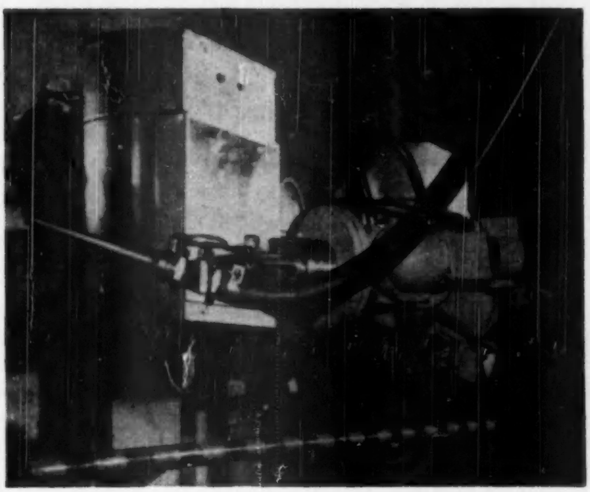


Fig. 4 In case of fire in a radioactive area hazardous to human fire fighters, the robot can man a hose effectively. In this picture, all it needs is someone to turn on the water back in a safe spot

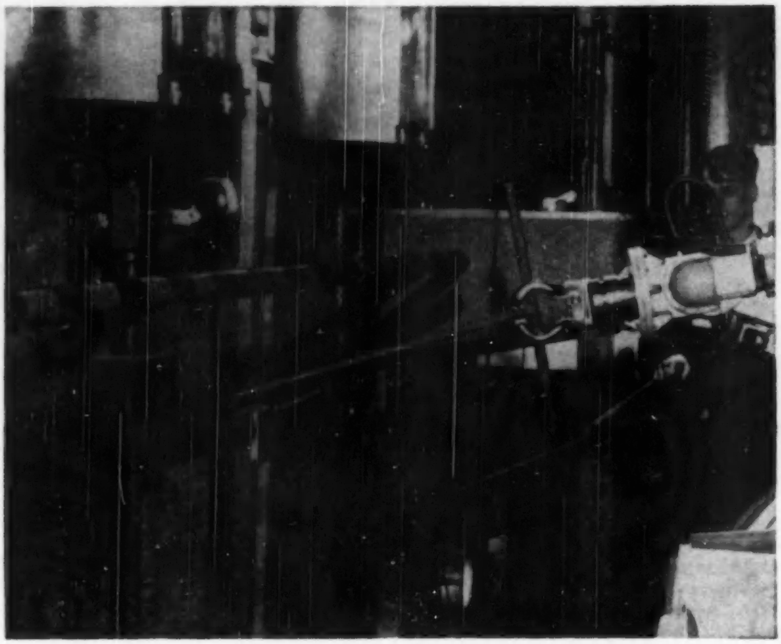


Fig. 5 Manipulating a wrench with dexterity, as shown in this picture, is a simple chore for the robot in its duties at the Hanford Works

with no experience at manipulating the hand have, after a few tries, succeeded in picking up dimes from a floor.

There are six small electric motors in the arm and hand, and two dozen of them in the entire unit. In addition to the general purpose hand, the dolly is equipped with an hydraulically-driven ram, electrically controlled, which can deliver a four-ton push; rotating devices for opening and closing valves; and several specialized attachments for taking apart or reassembling specific types of machinery.

A man operating the dolly must be able to see what the device is doing, and various methods for observing its movements from behind a shield can be used. To make observation easier, G-E engineers have equipped the dolly with a three-foot mirror, which is mounted high on the carriage, and which can be turned vertically or horizontally by remote control, so as to show the operator a reflection of work hidden from his direct line of sight.

The valve-turning attachments are equipped with electric "feelers", which indicate to the operator whether or not the valve handle is properly centered in the grasp of the turner.

G-E engineers say that a man can be trained to operate the dolly in a week. The controls are mounted in two boxes, about the size of small suitcases. There are 23 switches, nine of them for controlling the hand and arm. The control panels are also equipped with lights, which indicate the position of certain of the dolly's tools with respect to the apparatus being worked on. Six cables, each containing 25 different conductors, connect the controls to the dolly, it was explained.

Seventy Million Volt Electron Beam Produced by Synchrotron

Modification of synchrotron at G-E Laboratory makes it possible to lead the electron beam outside of vacuum chamber. With the 70,000,000 volt synchrotron the beam penetrates the air for many feet. The beam may be useful in the treatment of deep-seated tumors

A BEAM OF 70,000,000-volt electrons, which may open the way to new methods of treating disease and is believed to be the most energetic electron beam ever formed in open air, has been produced in the General Electric Research Laboratory in Schenectady.

This beam was produced recently with a synchrotron, built in the laboratory as part of a research project sponsored by the Office of Naval Research.

The device, first of its kind in the United States, has been operation for some time, generating X rays of about 80,000,000 volts energy. Only recently, however, has it been found possible to extract from within the atom smasher's vacuum tube the electrons which whirl around inside.

This is accomplished by two curved metal plates within the doughnut-shaped vacuum tube. With one plate charged to a high electrical potential,

Fig. 1 The 70,000,000-volt electron beam issues from this synchrotron

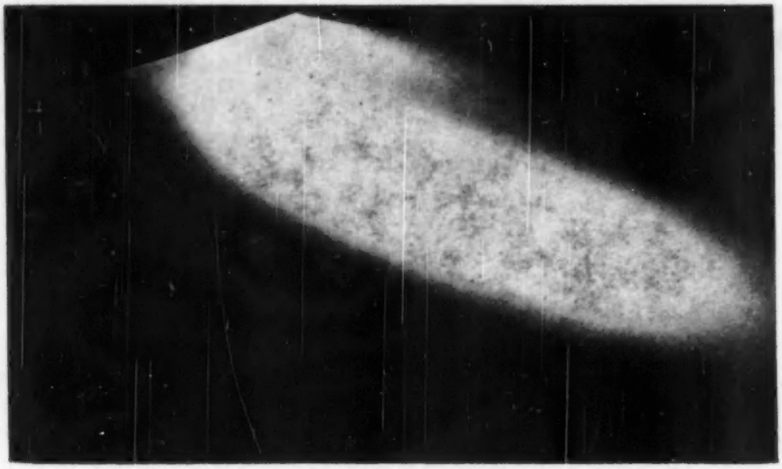


Fig. 2 A photograph of the 70,000,000- volt electron beam in air

they pull the electrons from their normal circular orbit inside the tube, aiming them at a thin foil window. Emerging from the tube, they penetrate the air for many feet, where they can be detected with a photographic film or other devices which are sensitive to such radiation.

Plans are being made for medical research with high-voltage X rays such as these normally produced with the synchrotron. A 70,000,000-volt synchrotron is now being constructed by the General Electric Co. for the Medical School of the University of California.

Though confirmation has yet to be obtained by medical scientists, Dr. Suits, Director of G-E Research, pointed out, it seems that a beam of electrons such as that now obtained in the air, might be more advantageous for some therapeutic techniques than one of X rays. In using the latter, with sufficient intensity to enable it to reach a deep-seated tumor, the radiation may do damage on the way in as it is partially absorbed by overlying healthy tissue. Use of X rays of higher energies has been found to minimize the effect, but it is believed that an electron beam might be still better.

In any X-ray tube, a beam of electrons must first be produced. When these are suddenly stopped by a metal target, X rays are generated. The synchrotron idea was suggested independently about 1944 by E. M. McMillan, of the University of California, and V. I. Veksler, a Russian physicist. Electrons, starting from a heated filament, whirl around inside a doughnut-shaped vacuum tube, placed between the poles of a powerful electromagnet. The magnetic field both guides the electrons in their circular orbits and gives them their initial acceleration, up to about 2,000,000 volts, at which their speed is nearly that of light. At this energy an oscillating electrical field, in a metallic gap through which the electrons have to pass, begins to operate and speed them further. When they have attained full energy they hit a tungsten target, and the X ray beam is formed. This entire process is repeated 60 times every second.

Dr. Herbert C. Pollock, G-E research physicist, and his associates in the X-Ray Division working with the 80,000,000-volt synchrotron, decided to employ electrically charged plates in seeking to extract the beam of

electrons. A theoretical treatment of the proceedings involved in electron beam extraction with the G-E synchrotron was made by Dr. Malcolm Hebb.

In the tube of the G-E synchrotron the curved plates, which may be about 11 inches long and of a material such as molybdenum, are about a tenth of an inch apart. They are placed inside the doughnut, but outside the normal electron orbit. The inner plate is grounded, while the outer is charged to a positive electrical potential of about 20,000 volts.

If the high frequency electrical oscillations that accelerate the electrons are turned off at the right time in their cycle, as the field is getting weaker, the electrons do not spiral inwards to hit the target. Instead, they spiral outwards, and enter the space between the curved deflecting plates. Since the electrons have negative charges, they are attracted by the positive charge on the outer plate, and are pulled outward still more. Thus they are aimed toward the thin foil window through which they pass for ultimate use.

Though Dr. Pollock and his associates have operated the synchrotron in a darkened room and used mirrors looking toward the beam, from behind a thick safety wall, they were unable to detect any visible glow around the beam. However, the electron beam can easily be recorded on a special photographic film, which is placed in the plane of the beam, between two blocks of wood, to simulate the absorption of tissue. With a few seconds exposure, a beam several inches long can be recorded. Because it is still in the field of the synchrotron magnets, the electron beam is curved, showing that it is not an X-ray beam, which would be unaffected by a magnetic field.

Atomic Fissions

News From The Atomic World

Status of Brookhaven Reactor

Unforeseen technical difficulties in design, engineering and construction have delayed completion of the nuclear reactor at the Brookhaven National Laboratory. The new research reactor originally scheduled for completion during the Fall of this year is now not expected to start operation for several months.

The major difficulties developed during testing of a new type air cooling system under simulated operating conditions. The tests revealed that the air duct work of the system as originally designed would not stand up under operating conditions, and important modifications in the design and construction of the cooling system are being made.

While alterations are being made on the cooling system, design and construction of other features of the pile, now 90 per cent complete, are also being rechecked.

Testing of reactor components and construction both before and after installation is extremely rigid. It is necessary to take out all the "bugs" before operation begins. To make alterations or repairs after the reactor begins to operate is extremely difficult and in some cases impossible.

Re-examination of the design and construction details of the pile is being done by scientists and engineers from Brookhaven National Laboratory,

the H. K. Ferguson Co., the engineering firm in charge of the reactor construction, and Babcock & Wilcox, consulting engineers. Staff members and consultants of the Atomic Energy Commission are also engaged in this work.

The expense of reviewing the design, engineering and construction and of making the necessary modifications in the structure will increase the estimated cost of the reactor and associated equipment by 6.5 per cent over the previous estimate, from $23,322,000 to $24,827,000.

The Brookhaven reactor is designed for use for research purposes, and is similar in type to the research reactor in operation at Oak Ridge National Laboratory. Both reactors operate with slow neutrons using natural uranium as fuel with a graphite moderator to slow down the neutrons.

The designed maximum power level of the new reactor will be 30,000 kw compared to 2,000 kw for the Oak Ridge reactor. This 15-fold increase in power level has markedly complicated the problem of cooling the enormous mass of uranium and graphite.

Other modifications in the design and construction of the Brookhaven reactor have been made to provide the greatest possible degree of flexibility in operation.

Electronic Selector in Atomic Energy Research

A recently developed type of mechanical brain which will sift through the mass of scientific knowledge continually pouring from laboratories and select those facts needed for specific research jobs is being perfected jointly by the U.S. Department of Agriculture and the Atomic Energy Commission. The machine, called the rapid selector, promises to help solve a crucial scientific problem of keeping the individual scientist abreast of the tremendous surge of new ideas and developments in his own and related fields.

The selector operates like a research worker looking through the cards in a library catalogue, but at much greater speed. With properly coded entries, the machine will scan up to 120,000 subject entries per minute, compared to a dozen or two entries which a fast worker may examine in the same time. Moreover, it will reproduce, on the spot, an abstract of a document or, if properly set up, the original document, saving time now spent in searching shelves of local libraries or in waiting for the information to come from distant places.

The present working model of the rapid selector stems from a suggestion of Dr. Vannevar Bush. wartime head of the Office of Scientific Research and Development. The development was carried out by Engineering Research Associates, Inc., under contract with the Office of Technical Services, Department of Commerce. Technical supervision of the project was provided by Dr. Ralph R. Shaw of the Library of the Department of Agriculture.

A 2000-foot reeel of film used in the present selector provides space for text and code for 60,000 abstracts or an equal number of text pages. As many as six different coded entries may be made for each abstract or page, or a total of 420,000 entries on the entire reel. If more entries are needed for complete coding of a single item the text is repeated, giving space for an additional six codes. Since the machine scans 500 feet of film per minute, the entire reel of film can be scanned in four minutes.

Scanning is done by means of banks of photo-electric cells which read the code. When the desired information comes along the cells trigger a camera equipped with a stroboscopic light source lasting two-millionths of a second. The short duration of the light source will effectively stop the moving film, producing a sharp image which may be enlarged for convenient reading.

First use of the selector by the Atomic Energy Commission will be for the maintenance of records of new research with radioisotopes, which are among the most important research tools of modern science. Isotope information will be catalogued by physical characteristics such as the energy and type of radiation, by applications such as use in medical treatment and diagnosis, by method of production, and other factors.

Saving in cost will be effected by supplying atomic energy libraries with reels of film instead of with the equivalent number of printed documents.

Potential Industrial Uses Among Subjects of Atomic Energy Reports

The effect of low dosages of radiation upon the blood count of exposed atomic energy workers, a novel method for detecting leaks in industrial chemical processing systems, a low-cost production method for industrial fluorine, and re-determinations of two basic properties of carbon, are among the subjects reported in 57 declassified and unclassified reports recently issued by Atomic Energy Commission laboratories.

These reports fall into five broad classifications: Biology and Medicine, 9 reports, 178 pages; Chemistry, 18 reports, 500 pages; Engineering, 14 reports, 162 pages; Mineralogy, Metallurgy and Ceramics, 5 reports, 250 pages; and Physics, 11 reports, 229 pages.

The work on blood counts of individuals exposed to ionizing radiation was done at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico, under the direction of Dr. Norman P. Knowlton, Jr. Dr. Knowlton found a small but significant decrease in the number of white blood cells in workers exposed to small but continuous doses of gamma radiation. The study was made of 10 men who received about 0.2 roentgens per week of gamma radiation for a period of more than 2 years. A second group of 46 persons exposed to 0.01 to 0.1 roentgen over the same period showed similar but less significant changes. Aside from the blood changes, the men studied showed no other signs of radiation effects. From these tests the scientist concluded that the routine blood count is probably the earliest and best available indicator of radiation effects.

A new leak detection method, called the halide torch method, is reported by Dr. A. C. Schmidt. The method was originally developed at the Radiation Laboratory, University of California in 1943. Since the method is more sensitive and rapid than the common soap bubble test widely used in industry, the halide torch method may have immediate industrial application. The test equipment consists of a burner, with an air intake through a 3-foot tube, which serves as the leak probe. A copper plate above the burner is made red hot. Freon or other halogen containing gases are introduced into the system being tested. If a trace of the halogen gas escapes from the system it is taken up by the air intake and reacts with the hot copper plate giving a characteristic bright green flame.

The use of fluorine and fluorine chemistry in industry is rapidly expanding, partly as a result of the impetus given fluorine research in connection with the wartime atomic energy development. Fluorine is one of the most vigorously reacting of the elements and fluorine compounds have valuable and unique properties. Such compounds require elementary fluorine in their preparation, but prior to the war cost of pure fluorine was one of the deterrent factors in its use. An electrolytic method for production of elementary fluorine developed in 1945 by the DuPont Corporation for the atomic energy program has brought down the cost of fluorine to the neighborhood of a dollar a pound. The high-lights of the processing methods are outlined in a report prepared by Dr. A. C. Stevenson.

A report by Drs. O. C. Simpson, R. J. Thorn, and G. H. Winslow, of Argonne National Laboratory, gives the latest results in a current project at the Laboratory to measure the heat of vaporization and vapor pressure of graphite. The significance of these measurements lies in the fact that thermodynamically graphite is a very stable form of carbon. From the heat of vaporization and vapor pressure scientists are able to calculate the strength of the bonds holding the individual carbon atoms together. Graphite therefore serves as a reference point for comparison of the strength of bonds and energy calculations of other carbon compounds, which include all organic materials such as coal, gasoline, organic dyes, rubber and foodstuffs.

Information on how to get any of these reports may be obtained from the Document Sales Agency, Atomic Energy Commission, Box E, Oak Ridge, Tennessee.

New Books on Atomics

Principles of a New Energy Mechanics, by Dr. Jakob Mandelker. First Edition; 6 by 9½ in., cloth, illustrated; 73 pages; published by the Philosophical Library, 15 East 40th St., New York, N. Y.; 1949. Price $3.75.

This book presents an entirely new conception of the whole body of science known as energy mechanics. This new mechanics, as the author points out in his preface, has been evolved from the same basic relations as Einstein's special theory of relativity, though not in the sense of his so-called postulates. The central notion of classical mechanics, the mass m, has been replaced in this mechanics by the superior energy conception of matter, mc^2. This important conception imparts its own higher order value to the new mechanics which conforms fully with the relativity principle, includes classical mechanics as a particular limiting case, and turns out, moreover, to be valid for high velocities.

The most significant result here is the new kinetic energy formula of a definite upper limit—something wholly unsuspected hitherto—which coincides exactly with the value for the radiating energy. While the new formula shows the classical value in the first approximation, it is entirely different from Einstein's kinetic energy formula.

This new energy mechanics represents the next step of an evolution leading from Newton's classical mechanics through Einstein's relativity theory as an intermediate stage.

As explained in the preface, in this new mechanics the result of Fizeau's experiment is precisely conformed. Furthermore, the Lorentz transition formula appears as a self-evident result, as does the dual character of force for rest and for motion. Moreover, the wave-corpuscular aspect of matter is presented

in an entirely new light, differing from De Broglie's basic conception; and finally, a satisfactory explanation is given for the half-quantum value of the zero point energy according to Schroedinger's wave equation.

Dr. Jakob Mandelker is Assistant Professor of Mechanics at the Georgia Institute of Technology at Atlanta, Georgia.

The Meaning of Relativity, by Albert Einstein. Third Edition, including the Generalized Theory of Gravitation; 5½ by 8 in.; cloth; 150 pages; published by the Princeton University Press, Princeton, New Jersey; 1950. Price $2.50.

This is the third edition of Mr. Einstein's classic presentation of his theory of relativity. The first edition, published in 1922, explained both the special and general theories of relativity and comprises the main body of this book. In 1945, Dr. Einstein added Appendix I covering significant advances since the original publication and in this new edition Appendix II presents a new generalized theory of gravitation which attempts to inter-relate all known physical phenomena. Dr. Einstein emphasizes the fact that the new theory has yet to be tested against experimental facts, but from its general characteristics he regards it as highly convincing. This publication of the generalized theory of gravitation may well rank with the original appearance of the theory of relativity as a milestone of scientific achievement.

The text of this book was first presented in lecture form at Princeton University in May 1921. Since that time Dr. Einstein has become a permanent resident of Princeton where he is a Professor at the Institute for Advanced Study. The original text of this book was translated from the German by Edwin Plimpton Adams, Appendix I by Ernst G. Straus and Appendix II by Sonja Bargmann.

Introduction to Atomic Physics, by Otto Oldenberg. First Edition; 6¼ by 9¼ in.; 366 pages; cloth; illustrated; published by the McGraw-Hill Book Co., 330 W. 42nd St., New York, 1949.

The title of this book is an excellent description of what this book really is. It is an introduction. Most recent books on atomic physics begin almost immediately with a consideration of nuclear forces and the structure of the nucleus. This book begins not with the nucleus but with atomic theory itself. The first chapters are concerned with the structural matter as revealed in chemistry. These chapters discuss the existence of the elements, the existence of atoms, the quantitative analysis of gases by volume, valence, atomic and molecular weights, the kinetic theory of gases, and material dealing with the masses and sizes of the atoms.

From there the book goes on to discuss the structure of electricity—that is, the evidence showing the existence of the electron. It describes Millikan's experiments, Richardson's equation and saturation current and space charge current in vacuum tubes. Next the book goes on to discuss the structure of light and the electronic structure of the atoms. This naturally involves the theory of spectra and the relations of the theory of spectra to the periodic table of the elements.

Only in Part VI do we come to the subject of nuclear structure. Part VI consists of five chapters—one on Isotopes; the second on Natural Transmutation and Radioactivity; third, Artificial Transmutation and Radioactivity; fourth, Applications; and fifth, Cosmic Rays. Among the applications is the uranium bomb and the uranium pile. Finally, in Chapter VII, there is a consideration of the Wave Nature of Matter.

This book is intended for readers who have taken a one year introductory physics course and are familiar with the elements of chemistry. Calculus is not

necessary for the understanding of atomic physics on the introductory level. Here the difficulty is not of a mathematical nature. It is difficult, however, to understand how thoroughly our detailed theory of atomic structure, although apparently remote from observed facts, is based on experimental evidence. Therefore, in this book the relation between theory and observed facts is stressed throughout. In one argument in which calculus is indispensable the mathematical treatment is relegated to an appendix. For more advanced students, many calculus problems are included.

In other words in this book the main emphasis is on understanding as opposed to accepting on authority. In many chapters of the book a method is applied that the author has tried out in elementary and advanced courses. Certain arguments that are essential parts of the course are relegated to problems. Through difficult problems the student is guided by a set of questions. This method serves two purposes—it is intended to stimulate the interest of the student and it impresses the student with the physical idea that is given in the problem as distinguished from the mathematical performance through which he is asked to go by himself.

In short, this is a very excellent book for those who wish to obtain a good background of atomic physics and who have not had very much training along these lines. Dr. Otto Oldenberg is Professor of Physics at Harvard University and the material in the book is based on a lecture course offered at Harvard University.

Out of My Later Years, by Albert Einstein. First Edition, 5¾ by 9 in.; 282 pages; cloth; published by the Philosophical Library Inc., 15 E. 40th St., New York, N. Y.; 1950. Price $4.75.

This second volume of collected essays by Albert Einstein covers a period of about 15 years from 1934 to 1950. The first anthology, published under the title, The World As I SEE It, comprised material from 1922 to 1934. In presenting this new collection of essays by the distinguished physicist, the publishers have made available Einstein's views as the philosopher and as a man. It is a treasure of living thought and a striking record of the titanic achievements of one of our most eminent contemporaries.

Albert Einstein does not belong to that group of scholars who live in the ivory tower of their research work, oblivious to the world around them. On the contrary, he has always been an astute and critical observer of the trends and needs of his time. Indeed, frequently did he intervene by written as well as spoken appeal and always we should like to emphasize for a humanitarian cause.

The various parts of this volume deal with personal credos, politics, education, the Jewish issue, war and peace, and also the fundamental principles of Physics. In several chapters the author explains his theory of relativity in such simple terms as to be understandable by every intelligent person. None of the essays were written before 1936, and many of them have never before been published in any form.

The book indicates that Albert Einstein's life and work are not confined to the problems of science alone. He is endowed with the awareness of the most urgent questions of modern society, social, religious, educational and racial relationships.

The Atomics Bookshelf

Introduction to Radiochemistry. By Gerhart Friedlander and Joseph W. Kennedy. John Wiley & Sons, Inc. $5.00

An excellent, up-to-date book describing the nature and applications of radioactivity without assuming previous knowledge of nuclear physics. It begins with a brief discussion of the historical background which is used as an introduction to the early chapters on descriptive information about atomic nuclei, nuclear reactions, and the apparatus used for the acceleration of nuclear projectiles. Later chapters discuss all aspects of nuclear phenomena.

Radioactive Tracer Techniques. By Geo. K. Schweitzer and Ira B. Whitney. D. Van Nostrand Co. $3.85

A useful manual designed to serve as a guide for laboratory work and instruction in the use of radioactive tracers. It should be of value to all who may have use for radioactive isotopes as tracers in industrial or medical applications.

The Atomic Story. By John W. Campbell. Henry Holt & Co., $3.00

By all odds the best and most interesting book on atomic energy for the layman. Written by a man who possesses the unique combination of writing ability and technical knowledge, it is first of all a story, not a treatise. At the same time it is accurate. It is the most important story of our time told in simple language by a man who has spent many years in the field of science fiction. He is the Editor of Astounding Science Fiction.

The Strange Story of the Quantum. By Banesh Hoffman. Harper & Brothers, $3.00

Easily the best account of the growth of the ideas underlying our present knowledge of atomic structure, prepared for the reader not especially trained in nuclear physics. It has taken one of the most abstruse and difficult questions—just how matter and energy are put together—and made it readable and understandable as it can be.

The Science and Engineering of Nuclear Power. Two Volumes. Edited by Clark Goodman. Addison Wesley Press, Inc., $7.50 each

These two volumes contain the essentials of a series of seminars initiated at MIT in October 1946. They provide, by far, the most valuable and usable technical material for the engineer available today. Their objective is to present the fundamentals of chain reacting systems in terms that are understandable to engineers interested in the industrial applications of nuclear energy.

Atomic Energy. By Karl K. Darrow. John Wiley & Sons, Inc., $2.00

The exciting story of the development of nuclear physics—a story climaxed by the reality of atomic energy and the atomic bomb. Told by an expert who can speak the layman's language.